The object of this study is the processes of assessing digital culture, the purpose is to devise methodological foundations for assessing digital culture in the systems of sustainable development of universities. The problem of insufficient methodological support for assessing digital culture makes it impossible to effectively manage the sustainable development of the university. The study is based on the example of projects carried out by students at the Lviv Polytechnic National University's course 'Fundamentals of Entrepreneurship and Business Planning Using IT', which applies digital technologies based on sustainable development. For the expert evaluation of the digital culture of student projects, a system of indicators has been formed that comprehensively covers it ('digital security', 'digital literacy', 'creativity in the digital environment', 'use of social networks and communications', 'innovation', 'digital rights and ethics'). The diversity of the indicators was agreed upon by establishing their significance and using the Saati pairwise comparison method. The substantiation of the digital culture indicators was implemented with the help of a mathematical model based on the matrix approach, using the methods of fuzzy set theory. The calculation of the significance of the digital culture indicators showed that the largest share is accounted for by the indicators 'digital literacy' (36 %), 'digital rights and ethics' (28 %), 'digital security' (16 %), 'creativity in the digital environment' (12 %). The lowest is 'use of social networks and communications' (4 per cent) and 'innovation' (4 per cent). In order to measure the level of digital culture, a pairwise comparison of the projects for each indicator was performed. On the basis of resulting estimates, the corresponding matrices of pairwise comparisons of projects were constructed, for each of which the measures of belonging of elements to a fuzzy set were established. The fuzzy sets were defined, which indicate the degree of certainty in the compliance of student projects with the indicators of digital culture. Based on the results of testing, the student project 'MyNature' satisfies the group of indicators of the level of digital culture by 71.2 %, 'HealthyWay' – by 53.5 %, '!!!Boooya' – by 48.8 %. The other projects – FizMat:), Medix, and 'Їііііsty!' – 36.3 %, 36.4 %, and 42.1 %, respectively

Keywords: digital culture, sustainable development, methodological foundations, university development strategy

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ASSESSMENT OF DIGITAL CULTURE IN SUSTAINABLE UNIVERSITY DEVELOPMENT SYSTEMS

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1. Introduction

Spreading the concept of sustainable development, which involves a balance between economic growth, social justice, and environmental protection, is a key vector of modern human life. Digital technologies are considered one of the most powerful tools for its implementation. Digitization and sustainable growth are characterized by mutual influence. On the one hand, sustainability concepts determine the use of energy- and resource-saving technologies, which is often achieved due to their automation and digitalization. On the other hand, sustainability guidelines contribute to the development of increasingly new digital technologies aimed at improving the management of natural resources, reducing waste, optimizing consumption, etc. The identified processes of interaction of sustainable development and digital technologies are mediated by digital culture, which creates new opportunities for such progress, but at the same time poses new challenges to humanity. Among them, the following are significant: the digital divide and digital dependence, the environmental effect of digitalization, data privacy and security, the impact of automation on the labor market, information overload and fake news, ethical issues of artificial intelligence, etc. Solving the problems of digital culture in the context of increasing the effectiveness of the implementation of the concept of sustainable development is one of the urgent tasks of modern economic science and practice.

In particular, the above is confirmed by data from the Pew Research Center [1], according to which 28 % of users consider disinformation to be the main problem of digital social media networks, which is spreading at a fast pace and mostly remains uncorrected. According to community anal-

ysis by The Enterprisers Project [2], 65 % of managers noted that they face discriminatory biases in artificial intelligence systems, which often reproduce or even reinforce them. After all, its algorithms are trained on data that may contain historical or social injustices: for example, discrimination in the field of lending, employment, court sentences. This level of digital culture makes it impossible to implement the goals of sustainable development.

From an environmental point of view, digital culture is characterized by even greater difficulties. For example, according to reports of the United Nations Environment Program [3], in 2021 53.6 million tons of e-waste were generated worldwide, and only about 20 % of it is properly recycled. The constant updating of gadgets and rapid replacement of old devices exacerbates this problem. Based on Sunbird data [4], it is clear that the energy consumption of digital infrastructure, in particular data centers, continues to grow. In 2022 they consumed about 460 TWh, which was about 1.3 % of the world's electricity consumption. It is expected that by 2026 this level will increase to over 1,000 TWh due to the increased use of artificial intelligence and cryptocurrency technologies.

The directions for solving the outlined problems are ensuring critical moments, identifying, and eliminating situations where an inappropriate level of digital culture can have a negative impact on sustainable development. Solving this issue should be approached comprehensively, implementing its solution in various sustainability systems. Among them, systems developed and implemented at universities are considered strategic. It is in the educational realm that the foundation is laid for the young generation to understand the principles of a balanced, harmonious, and fruitful coexistence of human and nature. Teaching students to care for the environment through the systematic implementation of sustainable development measures during the educational process should contribute to their understanding of responsibility for the results of their further professional activities. Accordingly, it will increase the level of their digital culture.

However, from a practical point of view, the theoretical, methodological, and applied support for solving the problems of digital culture on the basis of sustainable development is currently insufficiently developed. For example, the question remains open – how to measure the level of digital culture in the university, how to determine the problematic factors of digitalization that have a negative impact on the components of the system of sustainable development, how to ensure sustainable growth through the management of digital culture. Answers to these questions would make it possible to form scenarios for the university's exit from critical phases in sustainable development systems. In addition, it would help the participants of the educational process to reduce falling into digitalization traps, which lead to a decrease in the level of digital culture.

Our study of a number of Ukrainian universities testified that even while most of them have sustainable development strategies, there are methodological problems. Such as non-compliance with the principles of digital culture; lack of methods and models for assessing the level of digital culture on the basis of sustainability; failure to complete activities taking into account the goals of sustainable development in the educational process. This objectively makes further improvement of digital culture impossible.

The above erodes the foundations of the management of the systems of sustainable development at universities and inhibits the improvement of the level of digital culture. After all, without appropriate methodological support, it is not at all obvious how and to what level the state of digital culture should be studied, how to evaluate the results, based on which to adjust the scenarios of the university's sustainable development. Therefore, research aimed at solving the problems of evaluating digital culture in the systems of sustainable development at universities is relevant, scientifically and practically significant for modern science and practice in both educational-scientific and other sectors of the economy.

2. Literature review and problem statement

Our review of the related literature showed the multifaceted approaches of scientists to the issue of methodological support for the evaluation of digital culture in the systems of sustainable development at universities. In particular, the basics of awareness and the principles of the spread of digital culture are given in work [5], in which digital technologies are presented on the basis of a balanced theory and empirical analysis of their research. A similar scientific idea can be found in [6], the authors of which justify the concepts of the development of culture and society in the digital era. In the paper, the study of digital culture is reported as a means of understanding the digital society. The approach of scientists is based on the fact that the essence of the digital revolution is fully manifested in the cultural changes taking place in society. The indicated points of view reflect only fragments of the multifaceted issues of digital culture, but do not form methodologies for ensuring digital culture on the basis of sustainable growth.

On the other hand, a number of scientists consider the phenomenon of digital culture from the standpoint of the development of innovativeness. For example, methods of analyzing innovativeness, where elements of digital culture are presented, are outlined in [7]. Study [8] describes the requirements for establishing the level of digital culture in terms of determining the innovativeness of R&D products of industrial enterprises. However, these developments make it possible to use them when assessing the level of university digital culture only partially, which is due to their other target function. An option for solving this problem is the methods of evaluating the effectiveness of the implementation of immersive technologies described in [9]. This method is interesting from the point of view of evaluating elements of digital culture during the use of augmented and virtual reality technologies in the educational process, but it does not provide other evaluation situations. At the same time, despite the high scientific value of the cited works, they did not pay attention to the problems of digital culture on the basis of sustainability.

In part, the authors of [10] who carried out a systematic review of interactions between organizational culture, sustainability, and digitalization, resort to describing the relationship between digital culture and sustainable development. Scientists [11] also worked in this scientific area by considering the concepts of sustainable development and digital transformation. However, their studies do not mention universities, which are among the strategic participants in the global system of sustainable growth.

In the context of substantiating the connection between the concepts of digitization and sustainability, work [12] should be noted, in which the latter is differentiated by the

authors into ecological, economic, and social. The role of digital transformation to achieve sustainable development from the point of view of stakeholders is highlighted in [13]. In general, progress in the field of sustainable development on the basis of digital transformation is disclosed in [14]. In work [15], it is justified from the standpoint of economic sustainability, how new digital technologies can contribute to the transition to a sustainable economy of a closed cycle, an economy of digital exchange, as well as create sustainable production and infrastructure design. From this point of view, study [16], which highlights the relationship between digitization and sustainable development, is of scientific interest. Building on the study of the problem in this aspect, one should note the study of digital culture as a phenomenon within the scope of studying the subject of digital capital, presented in [17]. However, the cited works are mostly conceptual. From them, individual elements of the methodological toolkit for data collection and analysis of factors affecting digital culture under the conditions of sustainable development of universities can be obtained.

Considering the problem of evaluating digital culture on the basis of sustainable development from the standpoint of the efficiency of business entities, it is advisable to pay attention to work [18]. Its authors proposed a research model, which assumes that the development of a digital organizational culture contributes to both the process of digitalization of business and the creation of value with the help of digital tools, with the strategic goal of improving the results of the organization's functioning. At the same time, in this vein, paper [19] proved that the digitalization of products and services is mediated by market demands dictated by the innovative development of the creative economy. The value of this work in the context of the problem is that the elements of digitalization are considered by the authors in the context of the strategy of sustainable development of Ukraine and the world. This is also partially mentioned in [20], in which the issue of information support for the evaluation of achievements in the field of work using microdata, determined by the factors of digital culture, is raised. Separate methodical elements of digitalization analysis are substantiated in [21], in which scientists took into account the components of digital culture when determining the effectiveness of the organizational and economic mechanism of regulatory policy in agriculture. Some of the scientific ideas of this work, such as the use of a system of analytical indicators, can be applied to situations of evaluating digital culture in the systems of sustainable development at universities. Without diminishing the weight of the above developments, which are important ideologically, it should be noted that the practice of measuring the specified processes falls out of the scope of the presented studies.

Inadequate representation in the literature of methodological support for the assessment of digital culture at universities led to the need to change the approach to scientific research. In particular, it is appropriate to consider digital culture in various contexts of the educational and scientific environment.

For example, the authors of study [22] approached the consideration of this issue from a worldview, substantiating the principles of the development of digital consumer culture and its relationship with digital acculturation. They explained the reciprocal, iterative, and dynamic relationships between digital consumer culture and digital acculturation. However, no algorithm for determining the level of digital culture was given.

The methodical tools of digitization and sustainable development are given in [23], in which, in particular, approaches to teaching sustainable growth in the era of digital technologies are discussed. Important aspects of interaction between digital culture and education are presented in work [24]. In study [25], the concept of "digital culture" characterizes the processes of virtual exchange. Methodological developments proposed by these authors can be partially used within the framework of the specified problems. In particular, when establishing logical evaluative expressions for the purpose of comparing objects of digital culture. However, it also does not provide a comprehensive answer to the sought questions.

From a scientific point of view, the experience of countries in the world in the subject area is valuable for study. Approaches to the provision of public services for digital culture in China were analyzed in [26]; in work [27], issues of digital culture were considered within the framework of analyzing a number of economic processes of the Polish economy. However, the proposed methodological elements cannot be fully transferred to the systems of sustainable development at domestic universities. The reason is that the digital economies of these countries are significantly different from the Ukrainian one.

Therefore, the analysis of a significant number of studies in the field of science and practice of digitalization and sustainable development proved the practical absence of methods for evaluating digital culture in the systems of sustainable development at universities. The analyzed works present approaches aimed at solving the tasks of analyzing digital culture and ensuring sustainable development, but all of them are characterized by a fragmentary nature.

It should also be noted that, for the most part, the problems of digital culture are not considered in the context of the concept of sustainability. And therein lies a significant problem since it is digital tools that often act as mechanisms for implementing sustainable development.

The issues of developing indicators of the level of digital culture on the basis of the goals of sustainable development remain unresolved. The lack of such indicators and methods of their analysis and interpretation of results makes it impossible to define digital culture. Accordingly, it does not make it possible to substantiate the arguments regarding the improvement of the university's sustainable growth strategy. All this gives reason to assert that it is important to devise methodological principles for evaluating digital culture in the systems of sustainable development of universities, which will become a valuable basis for the practice of strategic management of them.

3. The aim and objectives of the study

The purpose of our study is to devise methodological principles for evaluating digital culture in the systems of sustainable development of universities. The results will make it possible, on the one hand, to measure the level of digital culture, which will contribute to deepening the understanding of the participants of the educational process of the positive and negative aspects of their activities from the standpoint of sustainability. On the other hand, the received assessments will serve as a basis for the formation of scenarios for adjusting student and teaching activities in the systems of sustainable development of universities, which will lead to

an increase in the level of digital culture. Methodological principles should become the basis for further use when justifying digitalization measures on the basis of sustainable development of universities.

To achieve this goal, the following tasks are set:

– to investigate the practical experience of implementing digital culture based on the principles of sustainable development of the university;

– to form indicators for expert evaluation of digital culture based on the principles of sustainable development of the university;

– to substantiate the mathematical model for assessing the level of digital culture on the basis of the sustainable development of the university;

– to evaluate the indicators of digital culture based on the principles of sustainable development of the university;

– to determine the level of digital culture based on the principles of sustainable development of the university.

4. The study materials and methods

The object of our study is the process of evaluating digital culture in the systems of sustainable development of universities.

In order to achieve the goal of the work, hypotheses have been formed that contribute to establishing the framework of this study and substantiating the expected results:

Hypothesis 1. Integrated indicators should be used to evaluate digital culture in the systems of sustainable development of universities, which could allow comprehensive analysis of student projects and other activities based on digitization.

Hypothesis 2. Our system of indicators for evaluating digital culture on the basis of sustainable development is universal for various types of projects, business areas, and all other factors of project work.

Hypothesis 3. The proposed system will make it possible to convincingly answer the question of which of the projects is the best in terms of the level of digital culture, based on taking into account all indicators.

The place of research implementation is the Lviv Polytechnic National University. The university has a developed development strategy "Lviv Polytechnic – 2025" [28], based on the goals of sustainable development, which is manifested at various levels of educational and scientific activity and various specialties of the university. Virtually all academic disciplines are mediated by sustainable development goals: most learning outcomes require the implementation of one or another goal. This testifies to the high level of spread of the ideology of sustainability among the participants of the educational process. A large number of educational disciplines are implemented with the help of digital technologies or for the results obtained on their basis, which gives reason to evaluate the results of these disciplines in terms of the level of digital culture mediated by the ideas of sustainable development. In particular, one of these disciplines is "Fundamentals of entrepreneurship and business planning using IT", which belongs to the list of university-wide optional disciplines. In the fourth semester of 2023/2024 this discipline was studied by 567 students of 17 specialties at the Lviv Polytechnic National University.

The chosen academic discipline was developed taking into account the provisions of the development strategy of the Lviv Polytechnic, which corresponds to the goals of sustainable development of the United Nations [29]. In particular, strategic goal 1: "Attract talented young people motivated to study at the university", strategic goal 2: "Create an environment favorable for study, work, and personal development."

In order to devise methodological principles for assessing the level of digital culture in the systems of sustainable development of universities, a mathematical model was built, based on the matrix approach and using methods of fuzzy set theory. Saati's method of paired comparisons was used in the justification. The matrix approach makes it possible to simplify multi-iteration calculations and reduce them to an integrated indicator of digital culture. The mathematical model constructed for evaluating digital culture on the basis of sustainable development at the university was tested on student projects of the educational discipline "Fundamentals of entrepreneurship and business planning using IT".

5. Results of devising the methodological principles for evaluating digital culture in the systems of sustainable development of universities

5. 1. Studying the practical experience of digital culture implementation based on sustainable development of the university

Our research was implemented on the example of the university-wide selective academic discipline at the Lviv Polytechnic National University – "Fundamentals of entrepreneurship and business planning using IT". It is taught by specialists of the educational program 6.051.00.03 "Business Economics" (bachelor's level of higher education). Main characteristics of the discipline: scope – 3 ECTS credits; field of knowledge – social and behavioral sciences, form of study – correspondence, full-time (3 or 4 semesters), type of control – differentiated assessment.

The analyzed course is determined by interdisciplinarity. The main goal is for students to learn the basics of entrepreneurial activity, in particular, the practice of developing innovative projects. To this end, during their studies, students master approaches to the generation of innovative ideas, methods of substantiating the validity of the idea from the market point of view, create and test a prototype of their product, build business models and market launch strategies, etc. One of the results, by which the level of knowledge acquisition by students is assessed, is the presentation of the representation of the product project developed during the semester.

An important feature of the discipline "Fundamentals of entrepreneurship and business planning with the use of IT" is the participation of students of various specialties of the Lviv Polytechnic. According to the terms of the course, students form teams (3–7 people) in which they work during the semester. Each member of such a team is responsible for a specific component of project work, which is a prototype of the construction of work in modern IT companies. At the same time, compliance with the goals of sustainable development is a mandatory condition for the implementation of the project. This approach is designed to help students understand the applied implementation of the ideology of sustainability, to master specific ways of observing digital culture in practice.

Student projects carried out using IT on the basis of compliance with the goals of sustainable development are

characterized by a certain level of digital culture. Having determined this level, analyzing the obtained results, one can gain an understanding of what exactly is a stumbling block in one or another type of project activity and make appropriate adjustments. This will enable students to see, through practical examples, how to adhere to digital culture on the basis of sustainable development.

To analyze the subject of the research, a sample of students was considered (4th semester, 2023/2024 year): 567 students of 17 specialties at the Lviv Polytechnic (in particular: "Computer technologies" – 37 %, "Software engineering – 17 %, "Comp "Computer linguistics" – 7 %, «Cyber security and information protection" – 7 %, "Information systems and technologies" – 6 %, "System Analysis" – 6 %, "Materials Science" – 5 %, "Biotechnology and Bioengineering" – 3 %, "Architecture and Urban Planning" – 4 %, "Marketing" – 5 %, and others – 3 %). A significant number of course participants testifies to the high level of its relevance and compliance with market demands. Such a sample provides a wide field of projects for evaluating the level of their digital culture, determined by the system of sustainable development of the university.

Within the framework of this study, a number of educational projects developed by students during 2024 were considered:

– the "MyNature" project is a mobile application designed to facilitate access to knowledge about nature and make the process of studying it interesting and accessible. The application makes it possible to identify plants and animals using a smartphone camera (the user can take a photo, and the application will identify the species and provide information and various interesting facts about it). The mobile application can characterize the location of the user and pull up information about natural phenomena and objects of this area. The project declares the offer of educational modules explaining natural processes;

– the "FizMat:)" project – a mobile application containing a large library of developed interactive materials for teaching mathematics and physics. In addition, a significant number of tests, physical-mathematical games, and competitions aimed at increasing the interest of young people in exact sciences are offered. Users of the application can share their experiences and discuss their results in the online community of participants;

– the "Medix" project – a mobile version of the web platform for use by medical students. It makes it possible to dive into individual systems of the human body and, in particular, to monitor how medications act on certain organs. The development makes it possible to see what is happening at the cellular level of tissues, as well as to virtually interact with various body organs in order to study them;

– the "HealthyWay" project is an application for smartphones that, with the help of monitoring functions, allows users to track their physical condition. These include activity level, sleep parameters, heart rate, weight and body mass index, blood pressure and glucose level, etc. Based on the data entered by the user (age, gender, activity level, etc.), the application can provide personalized advice on nutrition, exercise, and healthy sleep. The application can offer interactive training courses or programs on various topics: from nutrition and fitness to the basics of first aid and stress management;

– "!!!Boooya" project is a mobile application for learning foreign languages, including exotic dialects. The development provides a variety of lessons: grammar, vocabulary, reading, writing, and speaking. Users can communicate with native speakers in real time via chat, audio, and video. An interesting element of the application is the gamification of the learning process. In addition, the product uses adaptive algorithms that customize the learning process for a specific user: the program evaluates his/her progress and offers exercises according to the specified level;

– the project "*Їііііsty*!" is a web platform with which users can create a design and recipe of their own meal based on their interaction with artificial intelligence systems. In addition, the app offers thousands of recipes with step-by-step instructions, photos, and videos that help users prepare meals easily. Recipes can be divided into categories: national cuisine, level of difficulty, cooking time, dietary features, etc. The application also offers a list of recipes based on the user's food preferences.

All student projects were carried out taking into account the "Sustainable Development Goals by the UN" [29], which are included in the development strategy of the Lviv Polytechnic, and on which the system of its sustainability is based. In particular, goals related to human health and well-being (1–3, 8, 10, 16, 17), resource and energy conservation (6, 7, 11–15), development of industry, innovation, and infrastructure (9, 17), etc.

5. 2. Formation of indicators for expert evaluation of digital culture based on the principles of sustainable development of the university

To assess the level of digital culture on the basis of the university's sustainable development, a system of indicators should be formed that should comprehensively reflect its state. It is advisable to define the following as optimal indicators:

– digital security – an indicator designed to show the level of compliance with the protection of information, networks, software, devices from unauthorized access. Under the conditions of global digitization, the lion's share of daily human activity is transferred to the online space, which determines the need to protect personal and corporate data. The use of the digital security indicator of the student project will provide an understanding of how much the project is ready for practical implementation, how well it is developed and ready for market launch;

– digital literacy is one of the most important indicators of the proposed system because it proves the ability of students to effectively use digital technologies in order to solve project tasks. Digital literacy includes computer skills, the ability to critically analyze data, understanding the basics of cyber security, the ability to navigate in the digital space, etc. Taking this indicator into account in the digital culture evaluation system will allow us to see how deeply students possess digital skills and apply them in work on their projects;

– creativity in the digital environment. This indicator reflects the level of intellectualization of student development. That is, how creatively and innovatively the student approached the development of his/her product. The importance of creativity is quite high because it makes it possible to develop non-standard solutions designed to solve existing problems in the best way (satisfy a certain market need, solve a task that cannot be solved in a traditional way);

– use of social networks and communications – the indicator determines the level of understanding and ability of students to use social networks for effective commercialization and planning of further business activities for their projects. Social networks are used as a key tool for: exchanging information, forming relationships between people, organizations, and communities. They are also important for targeting audiences based on user experience and user

data analysis, developing a customer interaction strategy, launching advertising campaigns, etc. Social networks allow instant exchange of information, access to millions of users in the world. The use of this indicator in the digital culture evaluation system will indicate the level of students' understanding of the modern principles of digitalization of society;

– innovativeness as an indicator aimed at reflecting the level of innovative approaches used in student project activities (in particular, the ability to apply artificial intelligence, blockchain technologies, the Internet of Things, immersive technologies, etc.) Innovative technologies change approaches to product development in student projects and ways of their market development ;

– digital rights and ethics. This indicator reflects the level of students' understanding of human rights in the digital environment (privacy, protection against discrimination, freedom of expression, respect for copyright, etc.). At the same time, the ethics of developing and using student products play an important role.

An increase in the values of each of the indicators will lead to an increase in the level of digital culture in the projects as a whole.

As can be seen from the essence of our indicators, all of them are mediated by the ideology of sustainable development. It is here that the mutual influence of digital culture and the goals of sustainable development, which was outlined in the introduction to this study, is evident. A limitation of the system of indicators is their incomplete suitability for all types of projects. For example, strategic projects do not always require "Creativity in the digital environment". Also, not all business ideas require "Use of social networks and communications". The indicator "Innovativeness" can play a significant role at the beginning of project work, in particular, reflecting the level of intelligence embedded in it. However, over time, when a product is brought to market, the level of "innovation", as well as "digital literacy", will not change as much as the level of other indicators (for example, "digital security"). Therefore, hypothesis 1 is not fully true. Therefore, the system can be adjusted in terms of individual indicators that are responsible for certain relevant aspects of digitization.

5. 3. Substantiating a mathematical model for evaluating the level of digital culture based on the principles of sustainable development of the university

To evaluate and compare student projects from the discipline "Fundamentals of entrepreneurship and business planning with the use of IT" regarding the level of digital culture, they should be considered according to the set of proposed indicators. For the most part, in such cases, any indicators are multifaceted for experts, and therefore need to establish significance levels. Therefore, in order to find out the significance of indicators of digital culture, it is advisable to use Saati's method of paired comparisons.

At the same time, in a situation with unclear information provision, the significance of indicators must be calculated on the basis of the methods of the theory of fuzzy sets.

In the development of our approach to assessing the level of digital culture on the basis of sustainable development for student innovative projects, methodological provisions [30, 31] were used for the algorithmization of the comparative approach.

1 stage. To use Saati's method of paired comparisons, evaluations of the advantages of quality characteristics of student projects are determined on the basis of a nine-point scale. So, the levels of advantages of element w_i over w_j:

– "1 point" – there is no advantage of element w_i over w_j;

– "2 points" – the advantage of element w_i over w_j is almost weak;

– "3 points" – the advantage of element w_i over w_j is weak;

– "4 points" – advantage of element w_i over w_j is almost essential;

– "5 points" – the advantage of element w_i over w_j is significant;

– "6 points" – the advantage of element w_i over w_j is almost obvious;

– "7 points" – the advantage of element w_i over w_j is obvious;

– "8 points" – the advantage of element w_i over w_j is almost indisputable;

– "9 points" the advantage of element w_i over w_j is indisputable.

Taking into account the recommendations for the specified type of situations [31], the assessment is carried out for one element, and the level of predominance of other elements is established on the basis of the transitivity of logical considerations. That is, if the i-th component prevails over the j-th, and the latter has a certain advantage over the k-th, the only fair rule is that the i-th component outweighs the k-th more than the j-th. Evaluations are determined by experts. For further work, the minimum estimates of the advantages of other indicators over the i-th are chosen.

2 stage. The received expert evaluations are systematized in the form of a square diagonal matrix (1), which is inversely symmetrical:

$$A = \begin{array}{c} \\ w_1 \\ w_2 \\ \vdots \\ w_n \end{array} \begin{array}{c} \begin{array}{cccc} w_1 & w_a & \dots & w_n \end{array} \\ \begin{bmatrix} 1 & a_{12} & \dots & a_{1n} \\ \dfrac{1}{a_{12}} & 1 & \dots & a_{2n} \\ \vdots & \vdots & 1 & \vdots \\ \dfrac{1}{a_{1n}} & \dfrac{1}{a_{2n}} & \dots & 1 \end{bmatrix} \end{array}. \quad (1)$$

Inverse symmetry means that there are units on the main diagonal, and all other elements placed below it are inverses of the corresponding elements placed above. That is, for (1), the conditions are valid: $a_{ji} = \dfrac{1}{a_{ij}}, \quad i, j = \overline{1,n},$ where a_{ij} is an element located at the intersection of the i-th row and the j-th column; a_{ji} is an element at the intersection of the jth row and i-th column.

Considering the nature of transitivity of elements in matrix (1), comparative evaluations of other qualities of student projects on the subject of digital culture should be determined based on the expression:

$$a_{ij} = \frac{a_{kj}}{a_{ki}}, \quad i, j, k = \overline{1,n}, \quad (2)$$

where a_{kj}, a_{ki} are known elements of the k-th row (i, j columns). If an indicator (column name) prevails over another indicator (row name), the corresponding matrix element will be greater than one, and vice versa.

3 stage. The significance parameters (a_i) are determined using matrix (1) according to the expression:

$$a_i = \frac{1}{a_{1j} + a_{2j} + \ldots + a_{nj}} = \frac{1}{\sum_{i=1}^{n} a_{ij}} = \left(\sum_{i=1}^{n} a_{ij} \right)^{-1}, \quad (3)$$

where $a_{1j}+a_{2j}+...+a_{nj}$ are the elements of the jth column.

The degree of conformity $\mu_{ADVi}(P_s)$ of the S-variant of the project (P_s) to the i-th indicator is evaluated based on the results of project comparisons on the basis of pairwise comparison matrices. According to the results of the comparison of student projects for each indicator, the corresponding number of matrices of pairwise comparisons in the size $S \times S$ are made, where S is the number of project options.

Evaluation of student innovative projects is a rather multifaceted process, so we shall use the following data:

– a set of projects to be evaluated:

$P=\{P_1, P_2, \ldots P_s, \ldots P_S\}$;

– the set of indicators by which projects are compared:

$ADV=\{ADV_1, ADV_2, \ldots ADV_i, \ldots ADV_n\}$.

The correspondence of student projects to the i-th indicator is represented by a fuzzy set $\widetilde{ADV_i}$ on the set of P-variants:

$$\widetilde{ADV_i} = \left\{ \frac{\mu_{ADV_i}(P_1)}{P_1}, \frac{\mu_{ADV_i}(P_2)}{P_2}, \ldots \frac{\mu_{ADV_i}(P_s)}{P_s} \right\}, \quad (4)$$

where $\mu_{ADVi}=(P_s)$ is a measure of whether the element P_s belongs to the fuzzy set $\widetilde{ADV_i}$.

The best student project according to the level of digital culture is considered to be the one that will be the best in all indicators. Fuzzy solutions $\widetilde{D}$ are determined as the intersection of partial indicators:

$$\widetilde{D} = \widetilde{ADV_1} \cap \widetilde{ADV_2} \cap \ldots \cap \widetilde{ADV_n} = \\ = \left\{ \frac{\min\limits_{i=\overline{1,n}} \mu_{ADV_i}(P_1)}{P_1}, \frac{\min\limits_{i=\overline{1,n}} \mu_{ADV_i}(P_2)}{P_2}, \ldots, \frac{\min\limits_{i=\overline{1,n}} \mu_{ADV_i}(P_s)}{P_s} \right\}. \quad (5)$$

According to the resulting fuzzy set $\widetilde{D}$, in a situation with balanced indicators of project evaluation, the one with the maximum degree of belonging is considered the best:

$$\widetilde{D} = \arg\max\left(\mu_D(P_1), \mu_D(P_2), \ldots, \mu_D(P_s)\right). \quad (6)$$

In the case of imbalance of indicators, measures of membership to a fuzzy set $\widetilde{D}$ are calculated using the expression:

$$\mu_D(P_s) = \min_{i=\overline{1,n}} \left(\mu_{ADV_i}(P_s)\right)^{a^i}, \quad s=\overline{1,S}, \quad (7)$$

where a_i is the coefficient of relative importance of the indicator ADV_i, $\sum_{i=1}^{n} a_i = 1$, which concentrates the fuzzy set ADV_i according to the degree of importance of the indicator ADV_i.

5. 4. Evaluating the indicators of digital culture based on sustainable development of the university

Six selected student projects developed within the educational discipline "Fundamentals of entrepreneurship and business planning using IT" were considered: "MyNature" (P_a), "FizMat:)" (P_b), "!!!Boooya" (P_c), " Medix" (P_d), "HealthyWay" (P_e), and "*Їііііsty!*" (P_f) based on the digital culture indicators substantiated above:

– innovativeness (ADV_1);
– digital literacy (ADV_2);
– creativity in the digital environment (ADV_3);
– use of social networks and communications (ADV_4);
– digital security (ADV_5);
– digital rights and ethics (ADV_6).

Expert judgments obtained on the basis of pairwise comparisons of the first indicator (ADV_1) with others are summarized in matrix (8). Logical evaluation expressions are as follows:

– there is an undeniable advantage of ADV_2 over ADV_1;
– there is a weak advantage of ADV_3 over ADV_1;
– there is no advantage of ADV_4 over ADV_1;
– there is an almost significant advantage of ADV_5 over ADV_1;
– there is a clear advantage of ADV_6 over ADV_1.

The resulting expert positions make it possible to determine the following points:

$$a_{12}=9;\ a_{21}=\frac{1}{9};\ a_{13}=3;\ a_{31}=\frac{1}{3};\ a_{14}=1;$$

$$a_{41}=1;\ a_{15}=4;\ a_{51}=\frac{1}{4};\ a_{16}=7;\ a_{61}=\frac{1}{7}.$$

Thus, the diagonal inverse-symmetric matrix of comparisons will look like this:

$$A = \begin{bmatrix} 1 & 9 & 3 & 1 & 4 & 7 \\ \frac{1}{9} & 1 & \frac{3}{9} & \frac{1}{9} & \frac{4}{9} & \frac{7}{9} \\ \frac{1}{3} & \frac{9}{3} & 1 & \frac{1}{3} & \frac{4}{3} & \frac{7}{3} \\ 1 & 9 & 3 & 1 & 4 & 7 \\ \frac{1}{4} & \frac{9}{4} & \frac{3}{4} & \frac{1}{4} & 1 & \frac{7}{4} \\ \frac{1}{7} & \frac{9}{7} & \frac{3}{7} & \frac{1}{7} & \frac{4}{7} & 1 \end{bmatrix}. \quad (8)$$

As a result of applying expression (3) to each of the rows of matrix (8), the calculated significance of the indicators of the studied student projects will be, in particular:

– innovativeness (ADV_1):

$$a_1 = \frac{1}{1+9+3+1+4+7} = 0.04;$$

– digital literacy (ADV_2):

$$a_2 = \frac{1}{\frac{1}{9}+1+\frac{3}{9}+\frac{1}{9}+\frac{4}{9}+\frac{7}{9}} = 0.36;$$

– creativity in the digital environment (ADV_3):

$$a_3 = \frac{1}{\frac{1}{3}+\frac{9}{3}+1+\frac{1}{3}+\frac{4}{3}+\frac{7}{3}} = 0.12;$$

– use of social networks and communications (ADV_4):

$$a_4 = \frac{1}{1+9+3+1+4+7} = 0.04;$$

– digital security (ADV_5):

$$a_5 = \frac{1}{\frac{1}{4}+\frac{9}{4}+\frac{3}{4}+\frac{1}{4}+1+\frac{7}{4}} = 0.16;$$

– digital rights and ethics (ADV_6):

$$a_6 = \frac{1}{\frac{1}{7}+\frac{9}{7}+\frac{3}{7}+\frac{1}{7}+\frac{7}{4}+1} = 0.28.$$

Together, the above indicators will make up unity: 0.04+0.36+0.12+0.04+0.16+0.28=1.

Graphically, the calculated values of the significance of indicators of student projects are shown in Fig. 1.

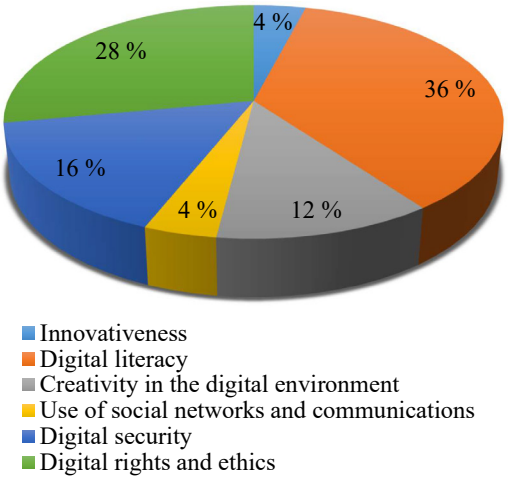

Fig. 1. Distribution of the significance of evaluation indicators for student innovative projects according to the level of digital culture

According to the results of our calculation of the significance of indicators, it is clear that the largest share belongs to "digital literacy" (36 %) and "digital rights and ethics" (28 %). After them, we note "digital security" (16 %) and "creativity in the digital environment" (12 %). The smallest share is "use of social networks and communications" (4 %) and "innovativeness" (4 %). Understanding the significance of student project evaluation indicators is the basis for further substantiating the level of digital culture for each of them. From the obtained data, it is clear that the value of digital literacy of project authors is significant, compared to other indicators, because it is the basis for the development of such projects. It is also important to observe rights and ethics in the digital environment, as well as understanding the principles of digital security. Failure to comply with at least one of the last two indicators can lead to a complete market fiasco of the project.

Within the framework of this evaluation process, individual indicators may not be fully suitable for a specific evaluation situation, or the possibility of their use only over a certain period of time. Then the system of indicators should be adjusted in part of the entered indicators since it is based on the algorithm of our model.

5. 5. Determining the level of digital culture of student projects based on the principles of sustainable development of the university

To determine the level of digital culture of student projects based on the principles of sustainable development, we shall perform a pairwise comparison of each of the six indicators, using point estimates of the predominance of one element over another (Table 1).

Table 1

Evaluation of student projects according to indicators of digital culture, based on the Saati scale

Indicator	Student's project ID	The nature of predominance of indicators	Indicators of the matrix of pairwise comparisons
Innovation (ADV_1)	«MyNature» (P_a)	An almost significant advantage over P_b	1/4
		A significant advantage over P_c	1/5
		Undoubted advantage over P_d	1/9
		An almost obvious advantage over P_e	1/6
		An almost obvious advantage over P_f	1/6
Digital literacy (ADV_2)	«FizMat:)» (P_b)	Undoubted advantage over P_a	1/9
		An almost significant advantage over P_c	1/4
		Undoubted advantage over P_d	1/9
		A significant advantage over P_e	1/5
		An almost obvious advantage over P_f	1/6
Creativity in the digital environment (ADV_3)	«!!!Boooya» (P_c)	Undoubted advantage over P_b	1/9
		A significant advantage over P_a	1/5
		Undoubted advantage over P_d	1/9
		Undoubted advantage over P_e	1/9
		Undoubted advantage over P_f	1/9
Use of social networks and communications (ADV_4)	«Medix» (P_d)	Weak advantage over P_b	1/3
		Weak advantage over P_a	1/3
		An almost significant advantage over P_c	1/4
		An almost significant advantage over P_e	1/4
		An almost significant advantage over P_f	1/4
Digital security (ADV_5)	«HealthyWay» (P_e)	A significant advantage over P_b	1/5
		A significant advantage over P_a	1/5
		Undoubted advantage over P_d	1/9
		A significant advantage over P_c	1/5
		Undoubted advantage over P_f	1/9
Digital rights and ethics (ADV_6)	«Ïiiiiisty!» (P_f)	A significant advantage over P_b	1/5
		An almost obvious advantage over P_a	1/6
		An almost obvious advantage over P_d	1/6
		A significant advantage over P_c	1/5
		An obvious advantage over P_e	1/7

Based on the indicators of the preferences of student projects, the corresponding matrices of pairwise comparisons were formed:

$$\mathrm{A}(ADV_1)=\begin{bmatrix} 1 & \frac{1}{4} & \frac{1}{5} & \frac{1}{9} & \frac{1}{6} & \frac{1}{6} \\ 4 & 1 & \frac{4}{5} & \frac{4}{9} & \frac{4}{6} & \frac{4}{6} \\ 5 & \frac{5}{4} & 1 & \frac{5}{9} & \frac{5}{6} & \frac{5}{6} \\ 9 & \frac{9}{4} & \frac{9}{5} & 1 & \frac{9}{6} & \frac{9}{6} \\ 6 & \frac{6}{4} & \frac{6}{5} & \frac{6}{9} & 1 & 1 \\ 6 & \frac{6}{4} & \frac{6}{5} & \frac{6}{9} & 1 & 1 \end{bmatrix}, \quad \mathrm{A}(ADV_2)=\begin{bmatrix} 1 & \frac{1}{9} & \frac{1}{4} & \frac{1}{9} & \frac{1}{5} & \frac{1}{6} \\ 9 & 1 & \frac{9}{4} & 1 & \frac{9}{5} & \frac{9}{6} \\ 4 & \frac{4}{9} & 1 & \frac{4}{9} & \frac{4}{5} & \frac{4}{6} \\ 9 & 1 & \frac{9}{4} & 1 & \frac{9}{5} & \frac{9}{6} \\ 5 & \frac{5}{9} & \frac{5}{4} & \frac{5}{9} & 1 & 1 \\ 6 & \frac{6}{9} & \frac{6}{4} & \frac{6}{9} & \frac{5}{6} & 1 \end{bmatrix},$$

$$\mathrm{A}(ADV_3)=\begin{bmatrix} 1 & \frac{1}{9} & \frac{1}{5} & \frac{1}{9} & \frac{1}{9} & \frac{1}{9} \\ 9 & 1 & \frac{9}{5} & \frac{9}{5} & 1 & 1 \\ 5 & \frac{5}{9} & 1 & \frac{5}{9} & \frac{5}{9} & \frac{5}{9} \\ 9 & 1 & \frac{9}{5} & 1 & 1 & 1 \\ 9 & 1 & \frac{9}{5} & 1 & 1 & 1 \\ 9 & 1 & \frac{9}{5} & 1 & 1 & 1 \end{bmatrix}, \quad \mathrm{A}(ADV_4)=\begin{bmatrix} 1 & \frac{1}{3} & \frac{1}{3} & \frac{1}{4} & \frac{1}{4} & \frac{1}{4} \\ 3 & 1 & 1 & \frac{3}{4} & \frac{3}{4} & \frac{3}{4} \\ 3 & 1 & 1 & \frac{3}{4} & \frac{3}{4} & \frac{3}{4} \\ 4 & \frac{4}{3} & \frac{4}{3} & 1 & 1 & 1 \\ 4 & \frac{4}{3} & \frac{4}{3} & 1 & 1 & 1 \\ 4 & \frac{4}{3} & \frac{4}{3} & 1 & 1 & 1 \end{bmatrix},$$

$$\mathrm{A}(ADV_5)=\begin{bmatrix} 1 & \frac{1}{5} & \frac{1}{5} & \frac{1}{9} & \frac{1}{5} & \frac{1}{9} \\ 5 & 1 & 1 & \frac{5}{9} & \frac{5}{5} & \frac{5}{9} \\ 5 & 1 & 1 & \frac{5}{9} & \frac{5}{5} & \frac{5}{9} \\ 9 & \frac{9}{5} & \frac{9}{5} & 1 & \frac{9}{5} & 1 \\ 5 & 1 & 1 & \frac{5}{9} & 1 & \frac{5}{9} \\ 9 & \frac{9}{5} & \frac{9}{5} & \frac{9}{5} & \frac{9}{5} & 1 \end{bmatrix}, \quad \mathrm{A}(ADV_6)=\begin{bmatrix} 1 & \frac{1}{5} & \frac{1}{6} & \frac{1}{6} & \frac{1}{5} & \frac{1}{7} \\ 5 & 1 & \frac{5}{6} & \frac{5}{6} & 1 & \frac{5}{7} \\ 6 & \frac{6}{5} & 1 & 1 & \frac{6}{5} & \frac{6}{7} \\ 6 & \frac{6}{5} & 1 & 1 & \frac{6}{5} & \frac{6}{7} \\ 5 & 1 & \frac{5}{6} & \frac{5}{6} & 1 & \frac{5}{7} \\ 7 & \frac{7}{5} & \frac{7}{6} & \frac{7}{6} & \frac{7}{5} & 1 \end{bmatrix}.$$

For each of the matrices formed above, measures of membership of the elements of the fuzzy set $\mu_{Gi}(P_i)$ were established (according to expression (3)). The results are the values of the membership functions $\mu_{Gi}(P_i)$ of element P_i in the fuzzy set $\widetilde{ADV_i}$. Therefore, the fuzzy sets certifying the degree of certainty in accordance with the student projects (P_a), (P_b), (P_c), (P_d), (P_e) and (P_f) to indicators $ADV_1 \div ADV_6$, are as follows:

$$\widetilde{ADV_1}=\left\{\frac{0.53}{P_a},\frac{0.132}{P_b},\frac{0.106}{P_c},\frac{0.058}{P_d},\frac{0.088}{P_e},\frac{0.088}{P_f}\right\},$$

$$\widetilde{ADV_2}=\left\{\frac{0.609}{P_a},\frac{0.064}{P_b},\frac{0.121}{P_c},\frac{0.067}{P_d},\frac{0.067}{P_e},\frac{0.067}{P_f}\right\},$$

$$\widetilde{ADV_3}=\left\{\frac{0.609}{P_a},\frac{0.064}{P_b},\frac{0.121}{P_c},\frac{0.067}{P_d},\frac{0.067}{P_e},\frac{0.067}{P_f}\right\},$$

$$\widetilde{ADV_4}=\left\{\frac{0.414}{P_a},\frac{0.16}{P_b},\frac{0.16}{P_c},\frac{0.104}{P_d},\frac{0.104}{P_e},\frac{0.104}{P_f}\right\},$$

$$\widetilde{ADV_5}=\left\{\begin{matrix}\frac{0.549}{P_a},\frac{0.109}{P_b},\frac{0.109}{P_c},\\ \frac{0.0549}{P_d},\frac{0.121}{P_e},\frac{0.058}{P_f}\end{matrix}\right\},$$

$$\widetilde{ADV_6}=\left\{\begin{matrix}\frac{0.54}{P_a},\frac{0.107}{P_b},\frac{0.088}{P_c},\\ \frac{0.088}{P_d},\frac{0.107}{P_e},\frac{0.108}{P_f}\end{matrix}\right\}.$$

Analyzing the results does not yield a convincing answer to the question of which of the projects is the best in terms of the level of digital culture, based on taking into account all indicators. The results are thus subject to clarification, in particular, taking into account the significance of the indicators.

Each of the components of fuzzy sets should be raised to the power of relative significance of indicator $a_1 \ldots a_6$.

$$\widetilde{ADV_1}^{a_1}=\left\{\begin{matrix}\left(\frac{0.53}{P_a}\right)^{0.04},\left(\frac{0.132}{P_b}\right)^{0.04},\\ \left(\frac{0.106}{P_c}\right)^{0.04},\left(\frac{0.058}{P_d}\right)^{0.04},\\ \left(\frac{0.088}{P_e}\right)^{0.04},\left(\frac{0.88}{P_f}\right)^{0.04}\end{matrix}\right\}=$$

$$=\left\{\begin{matrix}\frac{0.975}{P_a},\frac{0.922}{P_b},\frac{0.914}{P_c},\\ \frac{0.892}{P_d},\frac{0.907}{P_e},\frac{0.907}{P_f}\end{matrix}\right\},$$

$$\widetilde{ADV_2}^{a_2}=\left\{\begin{matrix}\left(\frac{0.40}{P_a}\right)^{0.36},\left(\frac{0.06}{P_b}\right)^{0.36},\\ \left(\frac{0.136}{P_c}\right)^{0.36},\left(\frac{0.0604}{P_d}\right)^{0.36},\\ \left(\frac{0.239}{P_e}\right)^{0.36},\left(\frac{0.0907}{P_f}\right)^{0.36}\end{matrix}\right\}=$$

$$=\left\{\begin{matrix}\frac{0.719}{P_a},\frac{0.363}{P_b},\frac{0.488}{P_c},\\ \frac{0.364}{P_d},\frac{0.597}{P_e},\frac{0.421}{P_f}\end{matrix}\right\},$$

$$\widetilde{ADV_3}^{a_3}=\left\{\begin{matrix}\left(\frac{0.609}{P_a}\right)^{0.12},\left(\frac{0.064}{P_b}\right)^{0.12},\left(\frac{0.121}{P_c}\right)^{0.12},\\ \left(\frac{0.067}{P_d}\right)^{0.12},\left(\frac{0.067}{P_e}\right)^{0.12},\left(\frac{0.067}{P_f}\right)^{0.12}\end{matrix}\right\}=$$

$$=\left\{\begin{matrix}\frac{0.942}{P_a},\frac{0.719}{P_b},\frac{0.776}{P_c},\\ \frac{0.723}{P_d},\frac{0.723}{P_e},\frac{0.723}{P_f}\end{matrix}\right\},$$

$$\widetilde{ADV}_4^{a_4}=\left\{\begin{matrix}\left(\frac{0.414}{P_a}\right)^{0.04},\left(\frac{0.16}{P_b}\right)^{0.04},\left(\frac{0.16}{P_c}\right)^{0.04},\\ \left(\frac{0.104}{P_d}\right)^{0.04},\left(\frac{0.104}{P_e}\right)^{0.04},\left(\frac{0.104}{P_f}\right)^{0.04}\end{matrix}\right\}=$$

$$=\left\{\frac{0.965}{P_a},\frac{0.929}{P_b},\frac{0.929}{P_c},\frac{0.913}{P_d},\frac{0.913}{P_e},\frac{0.913}{P_f}\right\},$$

$$\widetilde{ADV}_5^{a_5}=\left\{\begin{matrix}\left(\frac{0.549}{P_a}\right)^{0.16},\left(\frac{0.109}{P_b}\right)^{0.16},\left(\frac{0.109}{P_c}\right)^{0.16},\\ \left(\frac{0.0549}{P_d}\right)^{0.16},\left(\frac{0.121}{P_e}\right)^{0.16},\left(\frac{0.058}{P_f}\right)^{0.16}\end{matrix}\right\}=$$

$$=\left\{\frac{0.909}{P_a},\frac{0.701}{P_b},\frac{0.701}{P_c},\frac{0.729}{P_d},\frac{0.713}{P_e},\frac{0.634}{P_f}\right\},$$

$$\widetilde{ADV}_6^{a_6}=\left\{\begin{matrix}\left(\frac{0.54}{P_a}\right)^{0.28},\left(\frac{0.107}{P_b}\right)^{0.28},\left(\frac{0.088}{P_c}\right)^{0.28},\\ \left(\frac{0.088}{P_d}\right)^{0.28},\left(\frac{0.107}{P_e}\right)^{0.28},\left(\frac{0.108}{P_f}\right)^{0.28}\end{matrix}\right\}=$$

$$=\left\{\frac{0.842}{P_a},\frac{0.535}{P_b},\frac{0.506}{P_c},\frac{0.506}{P_d},\frac{0.535}{P_e},\frac{0.536}{P_f}\right\}.$$

The given fuzzy sets reflect the extent to which fully developed student projects (P_a, P_b, P_c, P_d, P_e, P_f) satisfy the indicators for selecting the best option $ADV_1 \div ADV_6$ (Table 2). Plots of the membership functions of the fuzzy sets obtained above are shown in Fig. 2.

Our research confirms that according to indicators of low significance, in particular "digital security" and "creativity in the digital environment", the differences between the projects have been smoothed out. In contrast to indicators with high significance – "digital literacy" and "digital rights and ethics". Therefore, it is quite difficult to select the best project.

The intersection of fuzzy sets $\widetilde{ADV}_i$ makes it possible to find out the best project and, in accordance with the degree of belongingness of the fuzzy solution $\widetilde{D}$, determines the degree of optimality of each of the evaluated project options:

$$\mu_D P_a=\min\begin{pmatrix}0.975;0.719;0.942;\\0.965;0.909;0.842\end{pmatrix}=0.719,$$

$$\mu_D P_b=\min\begin{pmatrix}0.922;0.363;0.719;\\0.929;0.701;0.535\end{pmatrix}=0.363,$$

$$\mu_D P_c=\min\begin{pmatrix}0.914;0.488;0.776;\\0.929;0.701;0.506\end{pmatrix}=0.488,$$

$$\mu_D P_d=\min\begin{pmatrix}0.892;0.364;0.723;\\0.913;0.629;0.506\end{pmatrix}=0.364,$$

$$\mu_D P_e=\min\begin{pmatrix}0.097;0.597;0.723;\\0.913;0.713;0.535\end{pmatrix}=0.535,$$

$$\mu_D P_f=\min\begin{pmatrix}0.907;0.421;0.723;\\0.913;0.634;0.535\end{pmatrix}=0.421.$$

Therefore, the fuzzy set of optimal solutions:

$$\widetilde{D}=\left\{\frac{0.719}{P_a};\frac{0.363}{P_a};\frac{0.488}{P_a};\frac{0.364}{P_a};\frac{0.535}{P_a};\frac{0.421}{P_a}\right\},$$

will make it possible to organize student projects according to the indicators of the level of their digital culture on the basis of sustainable development. However, it is impossible to state with certainty that among the analyzed student projects there is one that fully satisfies the developed system of indicators. The fuzzy set $\widetilde{D}$ is missing an element with a membership degree close to "1" $\left(\mu_{ADV_i}(P_s)<1, s=a,b,c,d,e,f\right)$.

Student project P_a ("MyNature") satisfies the group of digital culture level indicators by 71.2 %, project P_e ("HealthyWay") by 53.5 %, P_c ("!!!Boooya") by 48.8 %. The other projects, P_b ("FizMat:)"), P_d ("Medix"), and P_f ("*Ïiiiiisty!*"), satisfy 36.3 %, 36.4 %, and 42.1 %, respectively. So, student projects P_a, P_e, P_c are characterized by the highest level of digital culture.

Table 2

Calculated values of fuzzy sets based on student projects

Project ID	Innovation, ADV_1	Digital literacy, ADV_2	Creativity in the digital environment, ADV_3	Use of social networks and communications, ADV_4	Digital security, ADV_5	Digital rights and ethics, ADV_6
«MyNature»	0.975	0.719	0.942	0.965	0.909	0.842
«FizMat:)»	0.922	0.363	0.719	0.929	0.701	0.535
«!!!Boooya»	0.914	0.488	0.776	0.929	0.701	0.506
«Medix»	0.892	0.364	0.723	0.913	0.629	0.506
«HealthyWay»	0.907	0.597	0.723	0.913	0.713	0.535
«*Ïiiiiisty!*»	0.907	0.421	0.723	0.913	0.634	0.535

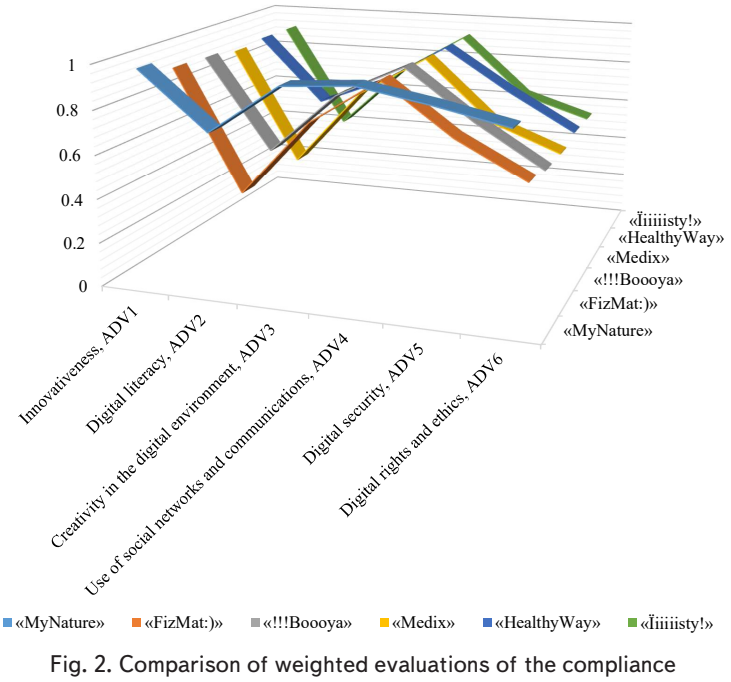

Fig. 2. Comparison of weighted evaluations of the compliance of student innovative projects with indicators of the selection of the best option $ADV_1 \div ADV_6$
Calculated by Authors

6. Discussion of results related to devising the methodological principles for the evaluation of digital culture in the systems of sustainable development of universities

To study the practical experience of implementing digital culture on the basis of the system of sustainable development of the university, an array of educational disciplines taught at the Lviv Polytechnic was considered. Among them, "Fundamentals of entrepreneurship and business planning with the use of IT" was chosen, where during the educational process digital technologies are used, aimed at ensuring the goals of sustainable development. Considering the fact that the subject is presented for all educational programs of the university, and it is interdisciplinary, students create teams to implement its project part. They can have participants from various specialties of the university, which simulates approaches to project work in IT companies. On the one hand, it makes it possible to combine specialists of various fields to work out a joint commercial idea, each of which will play an important role during the research and development of the product. On the other hand, all team members have the opportunity to see the full process of developing a business idea, and not only in part of their competences. Such a comprehensive approach contributes to increasing the level of digital culture of projects, since each of the components of this indicator is given the attention of the specialist responsible for it. The above testifies to the importance and convenience of further consideration of this academic discipline in relation to the assessment of digital culture.

In the context of the given topic, our study has made it possible to establish the defining aspects of the educational process within the discipline "Fundamentals of entrepreneurship and business planning using IT", in particular:

– the indicator of digital culture should be integrated, then its research on the example of the chosen discipline will contribute to understanding the advantages and "bottlenecks" of student projects in terms of specific components of digital culture. This confirms hypothesis 1. Moreover, the choice of this discipline not only made it possible to analyze the state of digital culture on specific projects but also to work out specific moments of the digital culture evaluation process (data collection practices and the formation of a mathematical model of their evaluation);

– in the analyzed student projects ("MyNature", "HealthyWay", "!!!Boooya", "FizMat:)", "Medix", "*Їііііisty!*"), ideas of sustainability are embedded, which correspond to the principles of the university's sustainable development system. However, the use of digital technologies for the realization of student ideas can bring not only advantages but also risks due to the progress of the digital world. Such risks are difficult to identify during project work, which takes place only during one semester. For example, ensuring digital security is a costly and time-consuming process. Therefore, this situation often makes it impossible to get projects with a high level of readiness for implementation and, accordingly, lowers the level of their digital culture. This is one of the limitations of project work within the discipline;

– obviously, the fundamental provisions of digital culture, determined by the ideology of sustainable development, should be announced to students before starting project activities. In order to pay attention to them, more deeply and qualitatively adhere to the indicators of digital culture at work.

To justify the level of digital culture inherent in student projects, a system of indicators for its evaluation has been built. Unlike known systems, the proposed one contains a number of indicators that comprehensively characterize the level of digital culture of the project, in particular digital security, digital literacy, creativity in the digital environment, use of social networks and communications, innovativeness, digital rights and ethics. A limitation of our system is the presence of situations where individual indicators may not be suitable for evaluating specific projects. For example, there are cases of products of strategic importance, for which the indicator "creativity in the digital environment" will have a somewhat limited expression. In addition, not all projects require "the use of social networks and communications" because there are many other ways of targeted promotion in networks. The indicator "innovativeness" can play a significant role at the beginning of project work because it proves the embedded intelligence. However, over time, during the market launch of the product, the level of "innovation" and "digital literacy" will not change as rapidly as the level of other indicators (for example, "digital security").

Therefore, it is possible to adjust our system in this part by introducing indicators that are responsible for certain relevant aspects of digitization. Therefore, hypothesis 2, which assumed the universality of the system for different types of projects, business areas and all other factors of project work, is not fully true: although it is universal, it is subject to adjustments in appropriate cases.

The application of our system of indicators for assessing the level of digital culture on the basis of the sustainable development of the university is substantiated with the help of a mathematical model based on the matrix approach and using the methods of the theory of fuzzy sets. It was noted that, for the most part, in the analyzed case, any indicators are multifaceted for experts, and therefore require the establishment of significance levels, therefore, the method of paired comparisons by Saati was applied. Based on studies [30, 31], the approach to project evaluation proposed there was advanced. In particular, the scale of item preferences has been added. Expert evaluations are systematized in the form of a square diagonal matrix, which is inversely symmetrical (4). This way of displaying expert evaluations makes it possible to simplify multi-iteration calculations and reduce to an integrated indicator of digital culture. The symmetry of the matrix contributes to the precision of the results. Such a matrix makes it possible to allocate computing resources in algorithms more efficiently. At the same time, it is determined by the transitivity of the elements. However, unlike those reported in [30, 31], our indicators make it possible to create further economic analysis in the system of sustainable development of the university.

The mathematical model operates with a set of student projects to be evaluated ($P=\{P_1, P_2, ... P_s, ... P_S\}$) and a set of indicators by which the projects are compared ($ADV=\{ADV_1, ADV_2, ... ADV_i, ... ADV_n\}$). The best project regarding the level of digital culture should be considered the one that will be better according to all indicators of the evaluation system. Among the equilibrium indicators of project evaluation, we consider the one with the maximum degree of relevance to be the best.

However, despite the optimization, an obvious drawback of the evaluation process is its complexity and multi-layeredness. Automation of calculations will help solve this, which is the subject of further research by our team.

The developed mathematical model for evaluating digital culture on the basis of sustainable development at the university was tested on student projects. In particular, "MyNature", "FizMat:)", "!!!Boooya", "Medix", "HealthyWay" and "*Їііііsty!*" based on justified indicators: "innovativeness" (ADV_1), "digital literacy" (ADV_2), "creativity in the digital environment" (ADV_3), "use of social networks and communications" (ADV_4), "digital security" (ADV_5), "digital rights and ethics" (ADV_6). Expert judgments obtained on the basis of pairwise comparisons of indicators with the use of logical evaluative expressions made it possible to obtain point evaluations of indicators and form a diagonal inverse-symmetric matrix of comparisons. The calculated significance of the indicators of the studied student projects will be, in particular: according to ADV_1, a_1=0.04; ADV_2, a_2=0.36; ADV_3, a_3=0.12; ADV_4, a_4=0.04; ADV_5, a_5=0.16; ADV_6, a_6=0,28, which add up to unity. Therefore, the largest share belongs to the indicators of "digital literacy" (36 %) and "digital rights and ethics" (28 %). After them, we note "digital security" (16 %) and "creativity in the digital environment" (12 %). The smallest share is "use of social networks and communications" (4 %) and "innovativeness" (4 %). The results are explained by the fact that the significance of the digital literacy of project authors is high, compared to other indicators, as it is the basis for the development of such projects. It is important to respect the rights and ethics in the digital environment, as well as to understand the basics of digital security. Failure to comply with at least one of the last two indicators can lead to a complete market fiasco of the project.

In this part of the assessment, there may be a limitation that was already mentioned in the proof of hypothesis 2 – the incomplete suitability of individual indicators for a specific assessment situation, or the possibility of their use only over a certain time period. In this case, the indicators in the system should be adjusted since it is based on the algorithm of our model.

The use of our proposed model has made it possible to establish the level of digital culture of student projects on the basis of sustainable development at the university. For this purpose, pairwise comparisons were made for each of the six indicators of our system, using point estimates of their predominance. Corresponding matrices of pairwise comparisons were formed, with the determination of the degree of belonging of the elements to the fuzzy set. Analysis of the results did not make it possible to convincingly answer the question of which of the projects is the best in terms of digital culture, based on taking into account all the indicators, which negates hypothesis 3. The results were refined taking into account the significance of the indicators. For this purpose, each of the components of the fuzzy sets is raised to the power of relative significance of the indicator a_1 ... a_6. Our results showed that according to indicators of low significance, in particular, "digital security" and "creativity in the digital environment", the differences between the projects were smoothed out, in contrast to indicators with high significance – "digital literacy" and "digital rights and ethics". Therefore, it is quite difficult to select the best project.

It was found that it is impossible to state with certainty that among the analyzed student projects there is one that fully satisfies the developed system of indicators. The calculation results showed that the student project "MyNature" satisfies the group of digital culture level indicators by 71.2 %, the "HealthyWay" project by 53.5 %, and "!!!Boooya" by 48.8 %. The other projects, "FizMat:)", "Medix", and "*Їііііsty!*", are satisfied by 36.3 %, 36.4 %, and 42.1 %, respectively. So, the highest level of digital culture characterizes the student projects "MyNature", "FizMat:)", and "*Їііііsty!*".

Thus, it can be stated that the proposed mathematical model for evaluating the level of digital culture on the basis of sustainable development of universities is suitable for practical use. It meets the research objective and gives valid results. However, the result is characterized by a number of limitations, which were discussed above. To avoid such limitations, this research should be developed towards adjusting the indicators of digital culture (in accordance with the topic and purpose of the project, its duration, etc.). An open question of this work is the study of reserves for changing the level of digital culture. Solving this task will make it possible to individually approach each project evaluation situation and understand the direction of managing their digitization based on the received evaluations.

7. Conclusions

1. Our research problem has been worked out using an example of the Lviv Polytechnic National University educational discipline – "Fundamentals of entrepreneurship and business planning with the use of IT", within which student teams carry out projects using digital technologies on the basis of sustainable development. Each participant is responsible for a specific component of project work, which is a prototype of the construction of work in modern IT companies. The team participation of students of various specialties at the Lviv Polytechnic is designed to give them an understanding not only of a profile fragment of the project but of its course as a whole. A mandatory condition for the implementation of projects is compliance with the goals of sustainable development, which are included in the development strategy of the Lviv Polytechnic, and on which the system of its sustainability is based. A significant sample (567 students of 17 specialties) made it possible to choose a number of projects for evaluating digital culture. In particular, such: "MyNature", "FizMat:)", "Medix", "HealthyWay", "!!!Boooya", "*Їііііsty!*".

2. For the expert assessment of digital culture based on the principles of the university's sustainable development, a system of indicators has been created that comprehensively reflect its state. For example, "digital security" gives an understanding – to what extent the project is ready for practical implementation, worked out and ready for market launch. "Digital literacy" certifies students' ability to effectively use digital technologies in order to solve project tasks. "Creativity in a digital environment" reflects the level of intellectualization of student development. "Use of social networks and communications" determines the level of understanding and ability of students to use social networks for effective commercialization and planning of further business activities for their projects. The use of this indicator in the digital culture evaluation system will indicate the level of students' understanding of modern principles of digitalization of society. "Innovativeness" as an indicator aimed at reflecting the level of innovative approaches used in student project activities. "Digital rights and ethics" reflects the lev-

el of students' understanding of human rights in the digital environment. All indicators are mediated by the ideology of sustainable development. In the course of the work, limitations of our system were revealed – incomplete suitability of all indicators for all projects.

3. When substantiating the mathematical model for assessing the level of digital culture on the basis of the sustainable development of the university, it was determined that the indicators are multifaceted for experts, so they need to establish levels of significance. To this end, Saati's method of paired comparisons was used. Expert evaluations of the advantages of quality characteristics of student projects were determined based on a nine-point scale, which were systematized in the form of a square inverse-symmetric diagonal matrix. This made it possible to simplify multi-iteration calculations and reduction to an integrated indicator of digital culture. The symmetry of the matrix contributed to obtaining significant accuracy of the results. The proposed approach has made it possible to allocate computing resources in algorithms more efficiently.

The mathematical model includes a set of student projects to be evaluated ($P=\{P_1, P_2, \dots P_s, \dots P_S\}$) and a set of indicators by which the projects are compared ($ADV=\{ADV_1, ADV_2, \dots ADV_i, \dots ADV_n\}$). According to the resulting model, the best project regarding the level of digital culture can be considered the one that will be better according to all indicators of the evaluation system. Among the equilibrium indicators of project evaluation, we consider the one with the maximum degree of relevance to be the best. Note that the disadvantage of the evaluation process is multi-iteration.

4. Six selected student projects were considered during the determination of the indicators of the digital culture assessment model based on the principles of sustainable development. All of them are developed within the framework of the educational discipline "Fundamentals of entrepreneurship and business planning using IT" based on well-founded indicators of digital culture. Expert judgments obtained on the basis of logical evaluative expressions made it possible to set points for the elements of the matrix and form it. Using the matrix, the significance of indicators of digital culture of student projects was calculated. In particular: according to ADV_1, $a_1=0.04$; ADV_2, $a_2=0.36$; ADV_3, $a_3=0.12$; ADV_4, $a_4=0.04$; ADV_5, $a_5=0.16$; ADV_6, $a_6=0.28$, which add up to unity. The largest share belongs to the indicators of "digital literacy" (36 %) and "digital rights and ethics" (28 %). After them, we note "digital security" (16 %) and "creativity in the digital environment" (12 %). The smallest share is "use of social networks and communications" (4 %) and "innovativeness" (4 %). It is clear from our results that the significance of the digital literacy of project authors is high, compared to other indicators, as it is the basis for the development of such projects. It is important to respect the rights and ethics in the digital environment, as well as to understand the basics of digital security. Failure to comply with at least one of the last two indicators can lead to a complete market fiasco of the project.

5. To establish the level of digital culture of student projects based on the principles of sustainable development at the university, first of all, their pairwise comparisons were made, according to each of our indicators, with the use of points for the predominance of one element over another. On the basis of estimates, corresponding matrices of pairwise comparisons were formed, to each of which measures of membership of the elements of the fuzzy set $\mu_{Gi}(P_i)$ were established. The results are the values of the membership functions $\mu_{Gi}(P_i)$ of element P_i of the fuzzy set $\widetilde{ADV_i}$ Fuzzy sets have been determined that demonstrate the degree of certainty in accordance with student projects (P_a), (P_b), (P_c), (P_d), (P_e) and (P_f) to indicators $ADV_1 \div ADV_6$.

Our results did not make it possible to make sure which of the projects was the best in terms of the level of digital culture, taking into account all the indicators of the system. Therefore, they were refined taking into account the significance of the indicators: each of the components of the fuzzy sets was raised to the power of relative significance of the indicator $a_1 \dots a_6$. The study showed that on indicators of low significance, in particular, "digital security" and "creativity in the digital environment, differences between projects are smoothed out, in contrast to indicators with high significance – "digital literacy" and "digital rights and ethics". Therefore, it is quite difficult to select the best project. The intersection of fuzzy sets made it possible to find out the best project and, according to the degree of belongingness of the fuzzy solution , determined the degree of optimality of each of the evaluated project options. Therefore, the fuzzy set of optimal solutions is as follows: $\check{D}=\{0.719/P_a; 0.363/P_b; 0.488/P_c; 0.364/P_d; 0.535/P_e; 0.421/P_f\}$. This will make it possible to organize student projects according to the level of compliance with the indicators of the level of their digital culture on the basis of sustainable development. However, it is impossible to state with certainty that among the analyzed student projects there is one that fully satisfies the developed system of indicators. In the fuzzy set $\check{D}$ there is no element with the degree of membership approaching "1" ($\mu_{Gi}(P_s)<1$, $s=a, b, c, d, e, f$).

Student project P_a ("MyNature") satisfies the group of digital culture level indicators by 71.2 %, project P_e ("HealthyWay") by 53.5 %, P_c ("!!!Boooya") by 48.8 %. The other projects, P_b ("FizMat:)"), P_d ("Medix"), and P_f ("*Ïiiiiisty!*"), satisfy 36.3 %, 36.4 %, and 42.1 %, respectively. So, student projects P_a, P_e, P_c are characterized by the highest level of digital culture.

Conflicts of interest

The authors declare that they have no conflicts of interest in relation to the current study, including financial, personal, authorship, or any other, that could affect the study, as well as the results reported in this paper.

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Data availability

The data will be provided upon reasonable request.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the current work.

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